

The Pan-Pacific Entomologist

VOL. XVIII, No. 3

July, 1942

BIOLOGY OF TWO NATIVE COLEOPTEROUS PREDATORS OF THE MOUNTAIN PINE BEETLE IN SUGAR PINE

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INTRODUCTION

Temnochila virescens (F.) (Ostomatidae) and *Enoclerus spegeus* (F.) (Cleridae) are recognized as important predators of bark beetles in the West. These two coleopterous insects are associated consistently with bark beetle infestations in most of the western pines. They are found also with infestations in white fir, red fir, and Douglas fir, but do not occur as regularly or in such great numbers in these trees as in the pines. *T. virescens* is also associated frequently with bark- and wood-borers infesting incense cedar and several hardwoods, including oak. Both insects are among the largest and are probably the most important of several species of predaceous Coleoptera associated with bark- and wood-boring beetles infesting western forests.

In sugar pine stands these predators are associated closely with the mountain pine beetle, *Dendroctonus monticolae* Hopk. *Temnochila virescens* develops on the beetles attacking the trees in the summer, and *Enoclerus spegeus* on those attacking the trees in the fall. Either species may be found in adult and larval stages at any time of the year, the adults preying on bark beetles from spring to fall and the larvae preying on the developing broods of the bark beetle. During the winter the adults hibernate in the bark crevices while the larvae remain inactive under the bark. The habits and possible controlling effect of adults and larvae have long been considered important in limiting the aggressiveness of the mountain pine beetle in sugar pine stands. For this reason detailed investigations of their life histories and behavior, which form the basis of this paper, were initiated as a preliminary step in determining the value of these two insects.

Except for one account of *Enoclerus spegeus* by Böving and Champlain (1920) the small amount of published information on the habits of these insects is quite general in character. These authors gave detailed information on the life history and the habits of this insect in its association with the Black Hills beetle, *Dendroctonus ponderosae* Hopk. They stated that this insect "should prove of great benefit as a predator on *Dendroctonus* and other bark beetles in coniferous trees during control operations." Brief discussions of both predators are contained in publications by Essig (1926), Doane et al. (1936), and Keen (1928). In a recent paper by Person (1940), *Temnochila virescens* is compared briefly with the black-bellied clerid, *Thanasimus lecontei* (Wolc.) in studies made on the association of this beetle with the western pine beetle, *Dendroctonus brevicomis* Lec.

The present paper considers primarily the developmental period from egg to adult and the feeding habits of adults and larvae. No attempt will be made here to evaluate the relative importance of the two species, since this information will be presented in a separate paper. Natural infestations, rearing records, and experiments, all concerned with the mountain pine beetle in sugar pine, supplied the factual material from which this contribution was prepared.*

TEMNOCHILA VIRESCENS (F.)

Seasonal Development and Habits

In its association with the mountain pine beetle, *Temnochila virescens* requires a full year to complete a life cycle. Eggs are laid from May to September in green trees freshly infested by the bark beetle. The larvae remain in these trees during the following autumn, winter and spring months. Pupation occurs late in the spring and early in the summer, and adults emerge from May to August, one year after the deposition of the eggs.

Figure 2 depicts a typical developmental cycle of *Temnochila virescens* in relation to its host, beginning in June of a given year and ending in July of the following year.

Adults. The adults (fig. 1, *A.*) are a brilliant, iridescent metallic blue or green, flattened and elongate, their length rang-

* Observations and experiments were made in the central Sierra Nevada Mountains near Wawona, California, at elevations between 4,500 and 6,500 feet, where optimum conditions prevail for sugar pine growth. Mountain pine beetle infestations here provided continuous material for the study of broods and variations during the period of this study from 1937 to 1940.

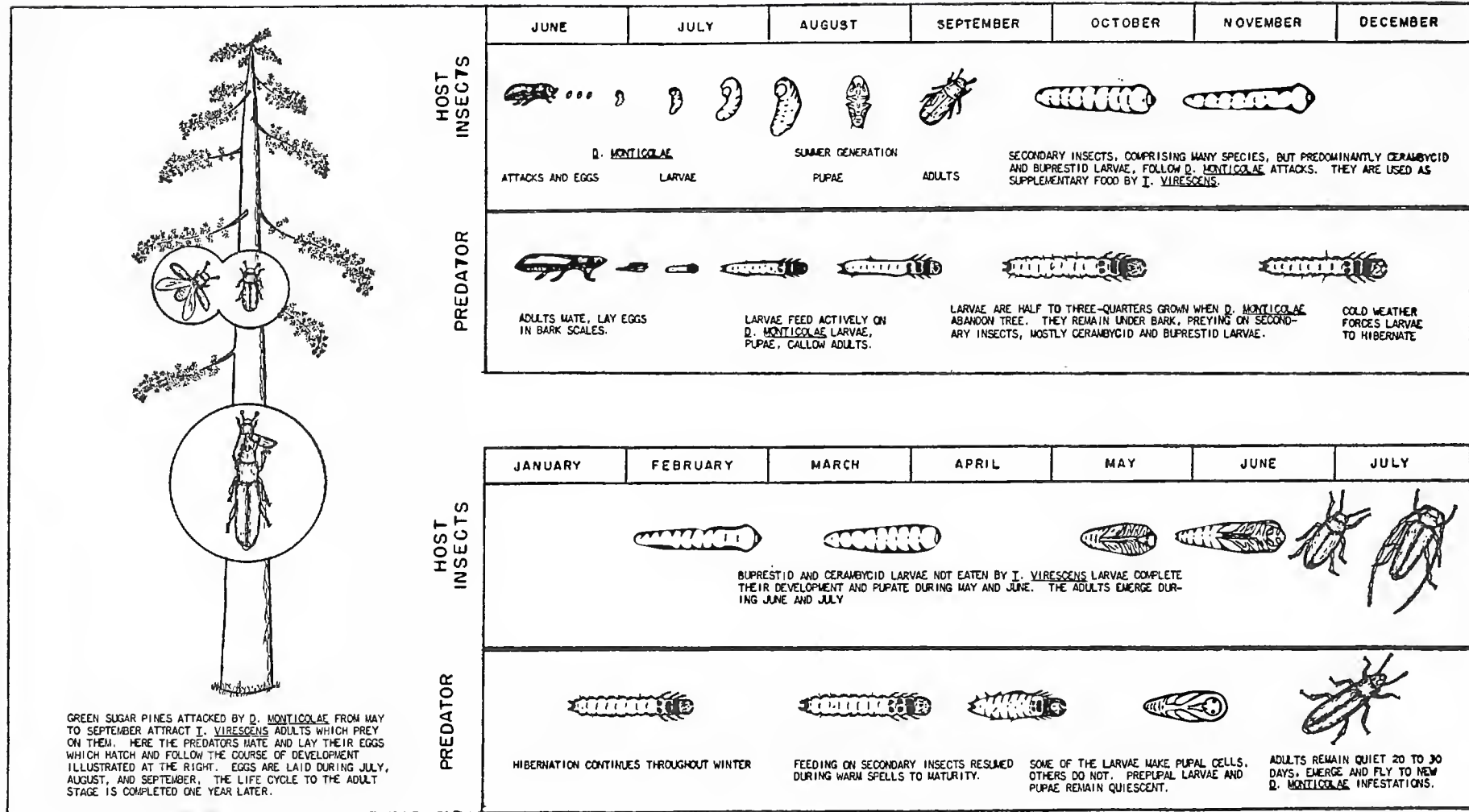


Fig. 2. Life cycle of *Temnochila virescens* in relation to *Dendroctonus monticolae* in sugar pine.

ing from 10 to 18 mm. In winter they hibernate in the bark crevices of infested trees, where they remain inactive until the advent of warm weather. From spring to fall they are most numerous on trees that are being infested by bark beetles, where they crawl stealthily over the bark and in the crevices searching out their prey.

They feed actively in confinement, consuming an average of from 1 to 3 mountain pine beetle adults per predator in a 24-hour period. Frequently as many as 15 bark beetles are killed, and many of these are devoured completely in a day by one large adult of *Temnochila virescens*. The predator kills by crushing the body of its victim with two powerful, piercing mandibles.

The ratio of males to females in the adults, as determined from 695 specimens reared in the laboratory from the egg stage, was 1.1 to 1.0. There is little reason to believe that the rearing environment or the small amount of handling would have had any influence on this ratio. It indicates an even distribution of sexes. Determinations were made by use of an external sex character described by Struble and Carpelan (1940).

A period ranging in length from 4 to 7 weeks is required before newly emerged females will deposit eggs. Whether this characteristic is influenced by food habits is not clear, but specimens under observation were fed frequently during the observed period. They were not compared, however, with unfed individuals. The total life period of both male and female adults ranged between 3½ and 8 months among specimens held in confinement and fed periodically. Females confined during the entire 8-month period at 75° F. laid eggs consistently each week, following the initial oviposition.

Eggs. The eggs (fig. 1, B) are 2.5 to 3 mm. long and 0.3 to 0.5 mm. wide, with pointed or rounded ends. The color is usually a delicate shade of pink, although some of the eggs are nearly white. They are deposited between bark scales, usually deep in the crevices of the bark, and often near the entrance hole of a bark beetle. Some are laid singly whereas others are deposited in groups of from 2 to 50 and are cemented together with a sticky secretion. The incubation period is 7 to 14 days under field conditions.

The number of eggs laid per female under laboratory conditions was found to range from 38 to 581. The average number

laid by 12 females during one experiment lasting 16 weeks was 111, with individual production ranging from 38 to 232 eggs. The viability of 2,500 eggs tested was 69 percent.

Larvae. The larvae (fig. 1, C) are from 25 to 30 mm. long at maturity. They are grayish white, with the head black and flattened. The dorsal surface of each of the first two thoracic segments is covered by a pair of black sclerotized plates, which are contiguous along the mid-line. In the third thoracic segment the dorsal sclerotized plates are smaller and separated from each other. The last abdominal segment is armed dorsally with a black, hardened hooklike process. There are three pairs of well-developed legs.

The first instars remain huddled together for 24 to 48 hours after hatching, and then scatter. They enter the bark usually through the entrance or ventilation holes of the mountain pine beetle. Within the inner phloem layer they search for and devour larvae, pupae, and callow adults of their beetle prey by burrowing through frass or through phloem tissue. They are not restricted in their diet to the mountain pine beetle, but prey indiscriminately on all living insects except the hardened mature adults. They are also highly cannibalistic, even in the presence of an ample quantity of other food.

For the first 2 months, larvae of *Temnochila virescens* feed actively on the brood of the mountain pine beetle. The average number of grubs devoured during this period ranges from 30 to 60 per individual. After that they are forced to feed on secondary fauna under the bark, mainly cerambycids, owing to the fact that the mountain pine beetle has completed its development and emerged. Observations have consistently shown that the larvae of this predator remain beneath the bark where they first established themselves.

To remain alive, newly hatched larvae must feed within 2 weeks, but after they have once fed they are capable of living many months without food. In five laboratory tests involving 117 newly hatched larvae, each in a separate container without host food, mortality consistently amounted to greater than 50 percent after 7 to 10 days and was 100 percent by the end of 2 weeks. In two other tests, involving 350 newly hatched larvae placed in separate containers, each larva was given 3 small larvae of the mountain pine beetle during a 10-day period in September, 1939.

Thereafter no host food whatever was given them; but in July, 1940, 10 months later, 178 larvae, or 50 percent of the original number, were still alive. Many of the others were found to have died from attacks by the mite, *Pediculoides ventricosus* (Newport).

By reason of great differences in the period required for brood development, larvae of *Temnochila virescens* are divided into two groups designated as *short-term* and *long-term* larvae. The short-term larvae, comprising not over 5 percent of the total number studied, required from 10 to 12 weeks to reach maturity at 75° F. The long-term larvae required 30 weeks to reach maturity at 75°, and 12 months under field conditions. The short-term larvae molted, consistently, five times during the course of their development. The long-term larvae were found to have an additional molt, with records of seven among some individuals. The cause of short-term development was not determined definitely, but studies indicated that it was not linked with the quantity of food eaten or with an hereditary strain. The number of short-term larvae in association with the mountain pine beetle are too few to be regarded as important.

Pupae. Pupation occurs usually within the bark or in the phloem, at or near the position occupied by the last instar. As a rule the larva hollows out a pupal cell, but not always, for the pupae are often found lying in loose frass beneath the bark. The pupae (fig. 1, *D*) are at first pinkish or cream colored, turning darker with age. The pupal period ranges from 11 to 20 days at field temperatures.

Natural Enemies

No important natural enemies of *Temnochila virescens* were found in any stage of its development under field conditions. This was also the case in laboratory rearing experiments except in the one instance wherein the mite, *Pediculoides ventricosus*, infested one group of larvae, causing considerable mortality. Adults occasionally become infested with a reddish-colored mite which does no apparent harm. In combination with the competition from other predaceous insect larvae associated with infestations of the mountain pine beetle, the factor of cannibalism tends to regulate its numbers.

ENOCLERUS SPHEGEUS (F.)

Seasonal Development and Habits

The red-bellied clerid, *Enoclerus sphegeus* (F.), develops one generation annually. The adults are found in September, October, and November in sugar pines that are being attacked by the mountain pine beetle. They remain in these trees, hibernating in the bark crevices during the winter months. Eggs are laid on warm days in the fall and again in the spring. The larvae reach maturity and migrate to the base of the tree to pupate by the time the host brood has begun to emerge in June. They remain inactive for 30 or more days before pupation.

Figure 3 illustrates a typical development cycle of *Enoclerus sphegeus* in relation to the overwintering generation of the mountain pine beetle in sugar pine.

Adults. The adults (fig. 1, *E*) are much more active than other bark beetle predators, and in their rapidity of movement resemble large flying ants or wasps. They range in length from 8 to 12 mm. They are bronze black with a transverse wavy bar of white pubescence across the middle of the elytra. The abdomen is bright orange. The entire body is covered by short white setae, giving it a grayish cast.

During warm weather in the fall and spring the adults are found running over the bark surface and darting among the cracks of recently infested sugar pines. They are difficult to catch because they hide quickly or fly away at the least disturbance. They are most numerous on the trunks of green trees that are being attacked by mountain pine beetles.

They prey on *Dendroctonus monticolae* in a manner characteristic of this insect. The adult usually approaches its prey from behind, but it may attack it from any position. Then, by quick and precise manipulation with the front and middle pairs of legs, it grasps the host and turns it over so that the ventral portion faces the mandibles of the attacker. Instantly it bites into the soft tissues between the head and thorax, or between the prothorax and the mesothorax, and drains the body of its juices and soft tissues. Wings, wing covers, and appendages are dismembered, and the body segments are torn apart. Only fragments of the host are left after 20 minutes to a half-hour of feeding. In

the laboratory the average number of *D. monticolae* devoured in repeated tests was about 1 beetle in 27 hours.

Enoclerus sphegeus adults are shorter lived than those of *Temnochila virescens*. Under laboratory manipulation involving mating pairs in individual containers the maximum life period was 2½ months, and the egg-laying period 8 weeks. This life period is considerably less than that occurring under field conditions where adults are known to hibernate during the winter. Often in the close quarters the nervous activity of the beetles led to entanglements which resulted in death to one of them, usually the male.

Eggs. The eggs (fig. 1, *F*) are pink or orange. They are cigar shaped and range in length from 3 to 4 mm. They are deposited beneath the bark scales, usually near the entrance hole of a bark beetle, in groups of 2 to 25, and are cemented together. In laboratory tests the average number of eggs laid per female was 51, the maximum 93, and the minimum 5. The incubation period ranges in length from 8 to 14 days under field conditions. Egg viability was somewhat less than 70 percent.

Larvae. The newly hatched larvae are pink or light orange. As they develop the color turns to deeper orange, and finally becomes a bluish purple in the last instar before pupation. Except for color the general appearance of the larvae (fig. 1, *G*) is similar to that of *Temnochila virescens*. The head and sclerotized portions of the thorax are brownish black; the thoracic spots are less conspicuous. The last abdominal segment terminates dorsally in a forked caudal appendage.

The larvae crawl readily by means of three pairs of well-developed legs. They begin migration to the interior of the bark within 24 to 48 hours after they have hatched in the fall or spring, entering usually through an entrance or ventilation hole of the mountain pine beetle. Beneath the bark they prey upon all stages of the mountain pine beetle brood except the mature adults. They are active feeders. Each larva requires approximately 10 mature larvae of the mountain pine beetle for complete development. They are also cannibalistic, especially within limited spaces.

Under favorable temperature conditions they develop to maturity in from 4 to 6 weeks, passing through three instars. Most of them are mature by the end of June among the overwintering

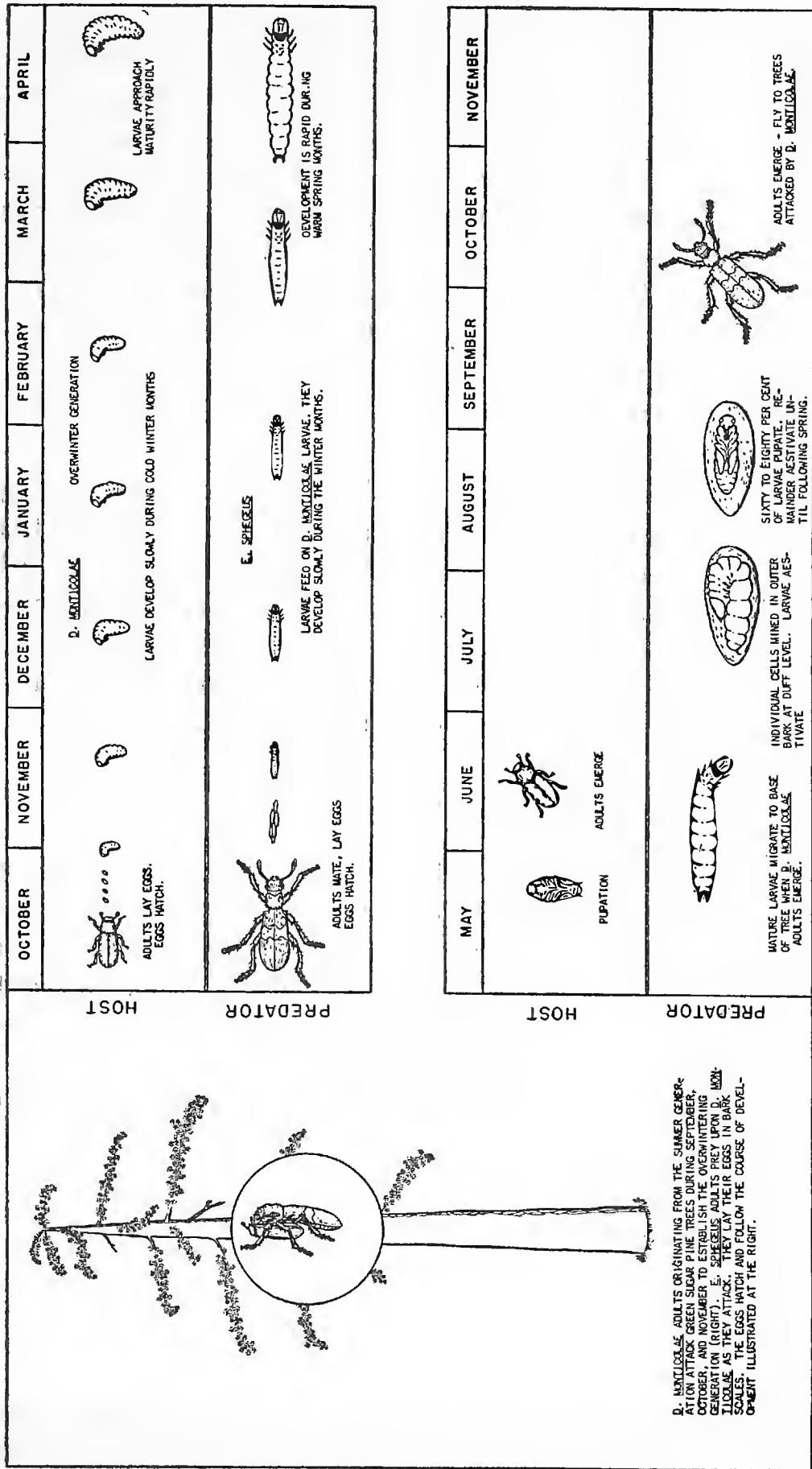


Fig. 3. Life cycle of *Enoclerus sphegeus* in relation to *Dendroctonus monticolae* in sugar pine.

broods of *Dendroctonus monticolae*. With the beginning of emergence of the mountain pine beetle the larvae migrate down the bole to the duff level, where they burrow into the outer bark. Each larva then hollows out a pupal cell, lining it with a silvery, foamlike secretion which exudes from the mouth. Then they remain quiescent in the cell with the head and thorax bent in against the abdomen. Within 30 days after this migration the larvae begin to pupate. About 30 percent do not pupate until the following spring, remaining unchanged throughout the summer and hibernating during the winter months. Pupal cells are found occasionally within the duff or in decomposing wood near the base of a tree when there is insufficient suitable bark, as is the case on trees heavily scarred by fire.

Pupae. The pupal stage (fig. 1, *H*) is found chiefly during August. The body portion of the pupa is light orange, while the appendages are nearly translucent. With advancement in age all portions turn darker. The pupal period at normal summer temperatures requires an average of 20 days before emergence of adults. Adults begin emerging early in September, but do not appear in numbers before October and November.

Natural Enemies

Like *Temnochila virescens* this insect is comparatively free from insect enemies. Reddish-colored mites were observed frequently on the adults, but these did not appear to affect them appreciably. Cannibalism, however, is common, and this habit may account for the death of many. The effect of other predaceous Coleoptera associated with *Enoclerus sphegeus* beneath the bark of infested sugar pines is probably negligible, since they are all very much smaller.

SUMMARY

Temnochila virescens and *Enoclerus sphegeus* are two native coleopterous predators of bark beetles and are commonly associated with infestations in many conifers in the West. In sugar pine they are associated with infestations of the mountain pine beetle. Their habits and life histories with this host were investigated as a preliminary step to determine their importance as control factors.

Both insects in the adult stage prey on mountain pine beetle adults as the latter attack green trees. In the larval stage they enter the bark to prey on the immature broods of the mountain pine beetle.

Each predator requires one year to complete development from egg to adult. *Temnochila virescens* develops its broods in trees attacked in the summer, whereas *Enoclerus sphaeus* develops its broods in trees attacked in the fall. Thus each predator is reared separately on the two seasonal broods of the mountain pine beetle.

Temnochila virescens lays its eggs from May to September. The larvae feed actively until the summer-generation broods of the mountain pine beetle take flight. They complete their development on secondary insects occurring beneath the bark. Adults emerge one year after the eggs are laid.

Enoclerus sphaeus lays its eggs during warm weather in the fall and spring. The larvae complete development and migrate to the base of the infested tree when mountain pine beetles begin flight in June. They pupate in cells during August. The adults emerge during September, October, and November.

Natural enemies of these two predators are unimportant, but cannibalism is a definite factor which tends to reduce their numbers.

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